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(54) Nozzle for turbofan aeroengines

(57) A primary or secondary flow nozzle which may form part of a cowling of a turbofan aeroengine has set of V-like notches cut into the walls of the nozzle at or close to the exit plane. The nozzle and notches may be terminated by a continuous elliptical or aerofoil section ring to provide structural integrity.

The V-notches may have a variety of possible configurations.

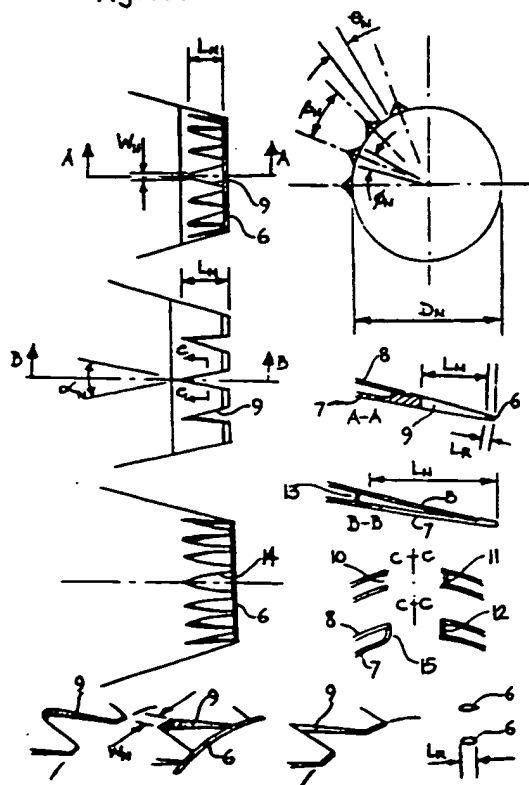
Among the advantages stated to result from the provision of the notches are:

a) Enhanced mixing of core and fan or/and fan and free-stream airflows;

b) Reduced efflux noise signatures;

c) Improvements in thrust-reverser mode of operation.

Figure 2



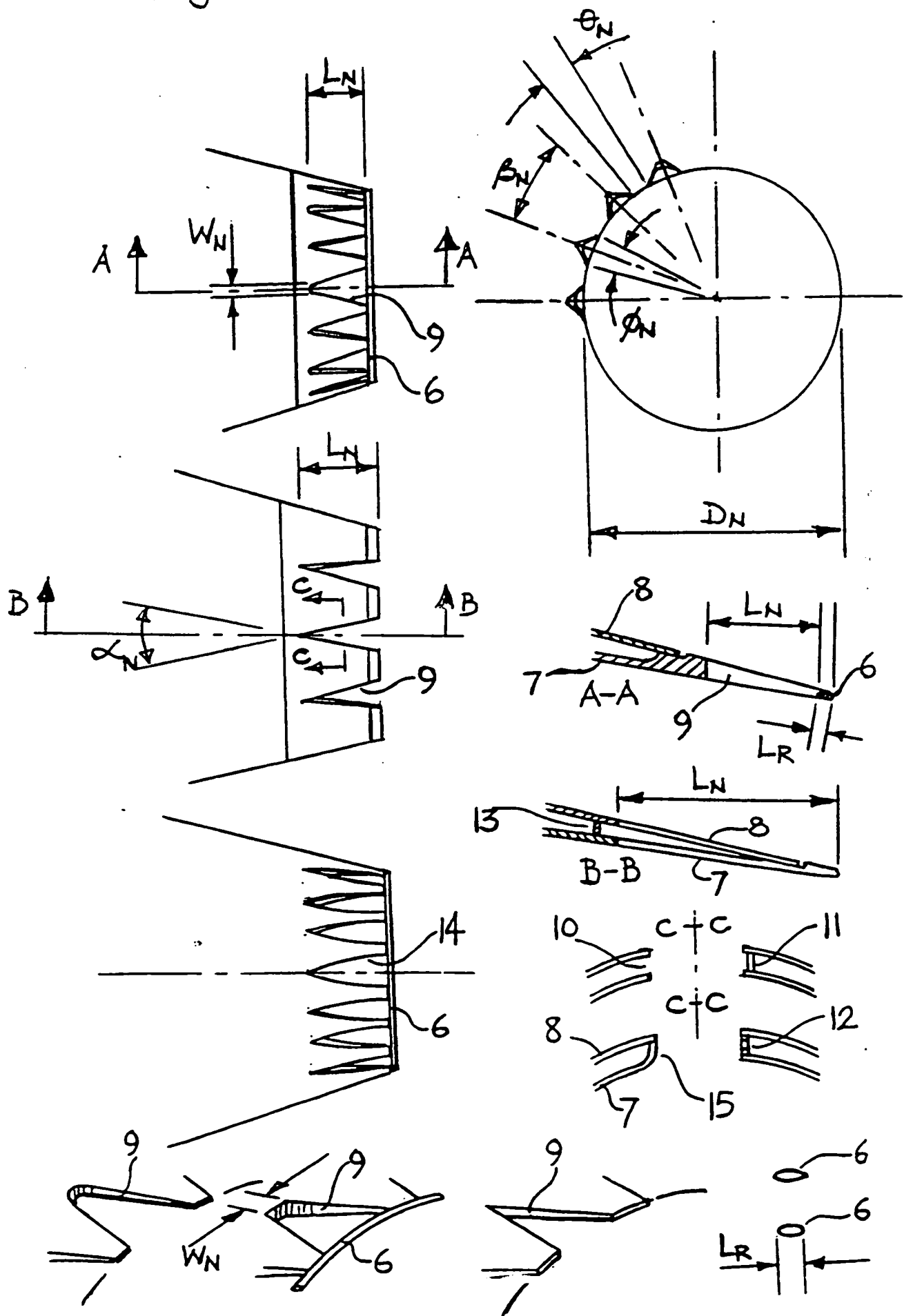
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CLAIMS

- 1 An aft cowl or nozzle of a turbofan aeroengine designed into the core cowl, and/or the fan cowl, and/or the cowling of the external mixed nozzle which includes a set of V-like cut-out notches cut through the walls of the nozzle or nozzles at or close to the nozzle exit plane or planes.
- 2 A nozzle or nozzles as claimed in Claim 1 in which the notches have a geometric form relative to the nozzle exit diameter within a specified range of a set of geometric variables as illustrated in Figure 2 and defined here as:
Total number of notches to be between 3 and 24;
Length of notches to be between 5 and 50% of nozzle exit diameter;
Angular width of notch in exit plane to be between 10 and 45 degrees;
Included angle of notch sides to be between 10 and 60 degrees;
Width of notch at apex to be between 0 and 20% of nozzle exit diameter;
Angular offset between notch centrelines to be between 10 and 120 degrees;
- 3 A nozzle as claimed in Claims 1 and 2 which has a streamlined sectioned nozzle closure ring at or close to the exit plane to provide structural integrity of a length specified relative to the nozzle exit diameter of between 0 and 20% of the nozzle exit diameter as shown in Figure 2.
- 4 A nozzle as claimed in Claims 1 to 3 having notches of equal or unequal form and in which the notches are distributed around the nozzle perimeter in a uniform or non-uniform arrangement.
- 5 A nozzle as in Claims 1 to 4 in which the notch side-lines are straight or curved and in which the notch side-line wall depth spaces are open or closed or vented and are of rectangular or curved sectional form as shown in Figure 2.
- 6 A nozzle or nozzles for a turbofan aeroengine as in Claims 1 to 5 substantially as described herein with reference to the accompanying drawings Figures 1 to 3 in which the geometric variables incorporated have been selected to yield high values of performance in respect to aero-thermodynamic efficiency and low noise and preferred thrust alignment and mixing performance for the required range of flight operations.

Figure 2

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curved form 14. The manner in which the notch sides are finished could also play a significant part in the noise and aerothermal performance and square cut 11 or rounded forms 15 are typical options. The optional nozzle closure ring 6 will typically be of elliptic or aerofoil section and the length of the ring will be significant in the performance of the design.

Tailoring of the number, location and size of the notches may lead to significant overall installed performance advantages; for example it may prove feasible to tailor the overall thrust vector orientation towards optimum requirements at high and low external (flight) flow speeds, using different notching in the upper and lower quadrants of a notched fan nozzle.

When notches are applied to the core nozzle of a SJ or LD design, Figure 3, a number of overall advantages can be envisaged. In the conventional operating mode the notches will result in enhanced mixing between the fan and core streams with possible attendant noise and aero/thermodynamic performance advantages. Also, in the thrust reverse mode of operations the availability of flow area in directions perpendicular to the nozzle axis should improve the effective area performance within a given length of cowls.

Figure 3 illustrates possible flow field features for a notched core nozzle design 16 of current interest in both the conventional and the reversed thrust modes of operation. It is part of the advantages claimed here for the notched nozzle that an optimally notched core nozzle in an LD layout can include some of the aero/thermodynamic and noise advantages of an LDFM design without the weight penalty related to the multi-lobe mixer of the LDFM. Furthermore, the notched core design is claimed to be more adaptable to the demands of the reversed-thrust design than conventional or forced mixer

Novel Nozzle Design for Turbofan Aeroengines

This invention relates to the design of the cowlings of the turbofan engines which are used to power most civil transport aircraft and which require compatible design solutions for the air intake and for the nozzle system.

In the design of the nozzle system there are a number of important constraints and requirements. Some of these are:

- a) Geometric constraints arising from upstream cowl and pylon design standards
- b) Fan and core nozzle effective area requirements
- c) Aero/thermodynamic performance
- d) Noise performance
- e) Mechanical complexity and weight
- f) Costs of manufacture and in-service maintenance and service life

Conventional turbofan nozzle systems generally employ one of the following overall design solutions (see Figure 1):

- i) Separate fan 1 and core nozzles 2, 3, fan annular, core circular 2 or annular with plug 3
- ii) Long duct mixed flow design with combined fan and core nozzle 4 and with a core nozzle of conventional (circular or annular) design submerged in the fan duct

iii) Long duct forced mixer design similar to ii) but with a special multi-lobe core nozzle S designed to enhance fan/core mixing rate to obtain enhanced aero/thermodynamic performance

These three main classes of nozzle system are referred to below as SJ (separate jets), LD (long duct combined flows) and LDFM (long duct forced mixing).

An additional factor which further constrains the design solutions is the need, generally encountered, for provision of reversed thrust during landing operations. This is invariably accomplished using some degree of variable geometry so as to reverse or divert the direction of the flow of the fan air and, sometimes also, the core flow.

It is the object of the current invention to make a contribution to the solution of the above requirements. The essential features of the current invention are a set of vee-like notches cut into the walls of the nozzle. Figure 2 shows a nozzle with vee-notches of typical layout.

The vee-notches may be uniformly or non uniformly distributed around the perimeter of the nozzle; also the notches in a given nozzle may be of equal or variable geometric size and form. Many variations in the geometric parameters defining the design are possible and the ranges of the variations of practical interest in this application are defined below; it is accepted that some of the ranges of variations cannot be mutually independently applied. The parameters and ranges of interest are as follows:

Total Number of notches, N

$$3 \leq N \leq 18$$

Length of notch, L_N/D_J
(based on nozzle diameter)

$$0.05 \leq L_N/D_J \leq 0.5$$

Angular width of notch
at nozzle exit plane, ϕ_N

$$10^\circ \leq \phi_N \leq 45^\circ$$

Angle of notch, α_N

$$10^\circ \leq \alpha_N \leq 60^\circ$$

Width of notch apex (flat), W_N/D_J
(based on nozzle diameter)

$$0 \leq W_N/D_J \leq 0.2$$

Angular offset between notches, β_N
(may be variable)

$$10^\circ \leq \beta_N \leq 120^\circ$$

Angular gap between notches
at nozzle exit plane, θ_N
(may vary around perimeter)

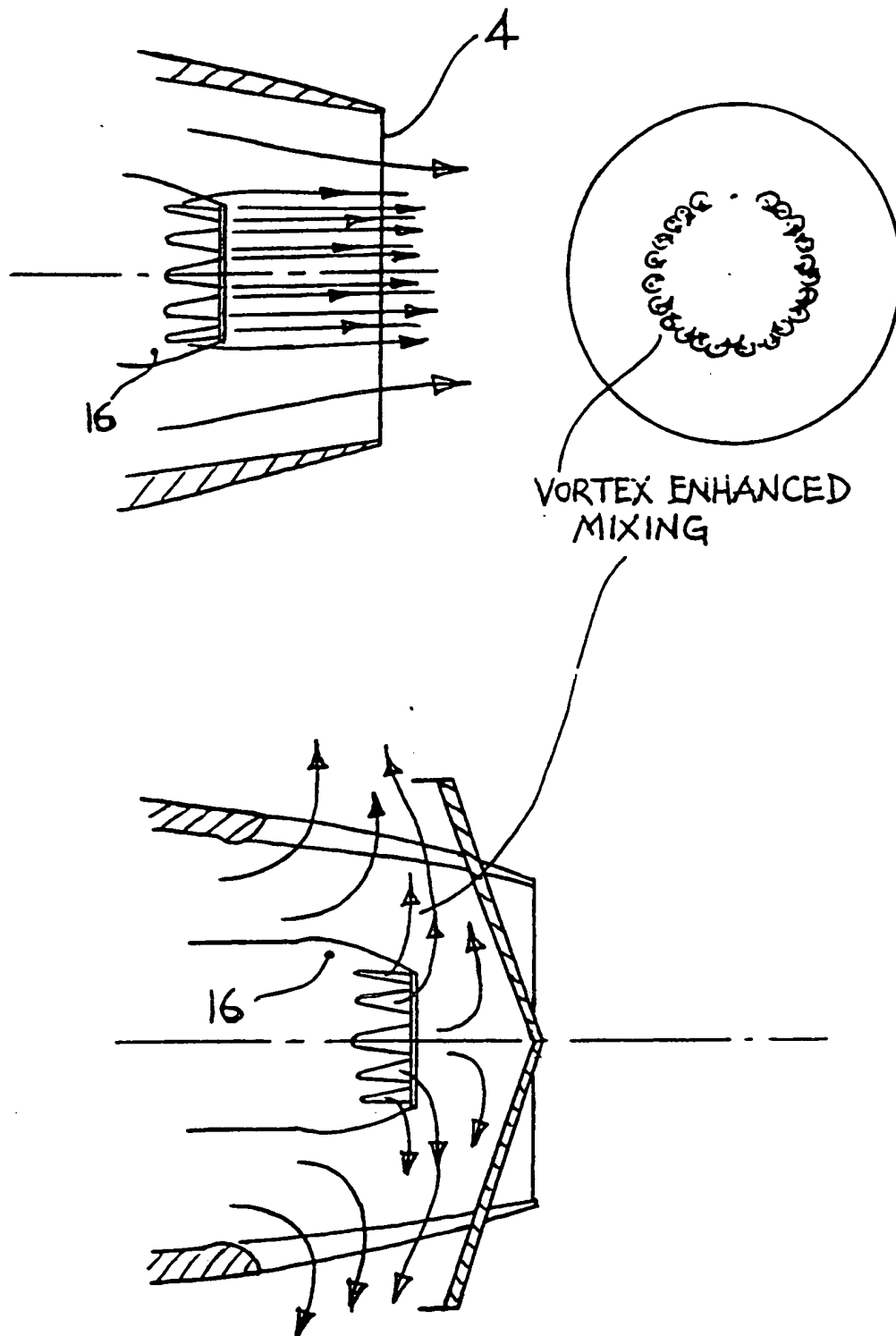
$$0^\circ \leq \theta_N \leq 120^\circ$$

Length of optional nozzle closure
ring δ , L_R/D_J
(based on nozzle diameter)

$$0 \leq L_R/D_J \leq 0.2$$

Recognising that the cowl frequently comprises an inner 7 and outer 8 layer near the forward end of the notch, the way in which the notch sides 9 are finished must be defined. Open sides 10 or closed sides 11 may be used or even part open sides 12. In the case of open or part open edges it is likely that some closure bulkhead 13 will be placed at a station close to the upstream limit of the notch. The upstream end of the notch may be of radiused, square or pointed form. It is possible that the sides of the notch may be straight 9 or of

Figure 3



arrangements, especially when overall cowl length and installed weight are considered. The introduction of notches in fan and/or core nozzle should permit significant changes in cowl lengths and/or afterbody angles leading to an improved overall merit rating based on the overall design requirements as outlined above. It is anticipated that these overall advantages can only be realised with very careful integration of the design for the various flight modes of operation and for the ranges of aero/thermodynamic conditions of internal and external airflows.

Figure 1

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